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NEW PATENT APPLICATION

ACTIVE VIBRATION REDUCTION

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ACTIVE VIBRATION REDUCTION

FIELD OF THE INVENTION

[0001] This invention relates generally to pump systems, in particular vacuum pump systems and ways to reduce the vibrations in such systems.

BACKGROUND

[0002] Pumps are widely used in industrial applications. Vacuum pumps are used in many applications in industries such as the semiconductor industry. For many processes it is necessary to create a vacuum in a process chamber. For example, chemical vapor deposition, sputtering and etching are all carried out in a vacuum environment and so equipment for these processes is generally connected to a vacuum pump or a system of vacuum pumps.

[0003] Semiconductor processing normally takes place in an extremely clean, controlled environment. Small particles of foreign material can damage semiconductor devices so great care is taken to eliminate any such particles from the manufacturing area. Small changes in the environment may affect sensitive processes. To overcome these problems, a "fab" is created in which the air is filtered and factors such as temperature and humidity are carefully controlled. Maintaining this environment is extremely costly. Some equipment that is not directly used to process semiconductors may be located outside of the fab. Vacuum pumps are often located outside the fab. Frequently, such pumps are located in a "sub-fab" (basement underneath the fab) that is maintained at a lower level of cleanliness than the fab area.

[0004] Certain semiconductor equipment requires a high level of vacuum that is achieved with a turbomolecular pump (TMP). TMPs have a rotor with blades that cause gas molecules to be expelled from the pump when they strike the blades. The rotor typically spins at extremely high speeds. Therefore, good bearings are important. One type of bearing that is used for this application is a magnetic bearing. This allows the rotor to spin without physically contacting the static portion of the pump. Passive magnetic bearings and active magnetic bearings are used. Active magnetic bearings have electromagnets that maintain the position of the rotor. If the rotor position changes, the change is detected by a sensor and the current to the electromagnets is adjusted to bring the rotor back to its intended position. Typical arrangements of magnetic bearings in a TMP include having a passive bearing holding the lower end of the rotor and active bearings at the upper end controlling the x, y and z-axis position of the upper end. Alternatively, active bearings may be used at the lower end also.

[0005] TMPs generally operate at reduced pressure (sub-atmospheric pressure). Therefore they are usually configured with a backing pump. A backing pump is a second pump that reduces the pressure at the exhaust side of the TMP. The backing pump reduces the pressure to a point where the TMP can operate efficiently. Typically a backing pump is a dry pump that is located outside the fab in a sub-fab area. Figure 1 shows a typical arrangement of a semiconductor processing tool with pumps where a TMP is located in the fab and its backing pump is placed in a sub-fab. Examples of such tools include cluster tools that deposit layers by chemical vapor deposition (CVD) or physical vapor deposition (PVD) and tools that etch material from a substrate.

[0006] Certain problems arise as a result of placing a backing pump away from a TMP. The line connecting the TMP to the backing pump (the foreline) may be long and have a significant volume. This adds to the time required to pump down the chamber and may necessitate a larger backing pump. Different foreline configurations may be required for different chambers

because of obstructions and varying distance between the TMP and backing pump. These different configurations may result in process variation from one chamber to another that is highly undesirable.

[0007] An alternative arrangement is to place the backing pump close to the TMP. The backing pump may be in the fab, connected to the TMP. The TMP, in turn, is connected to a processing chamber. By keeping these components close together, foreline induced variations may be eliminated; a smaller, cheaper backing pump may be used; costly foreline installation may be avoided and space may be saved in the sub-fab area.

[0008] One problem encountered when a backing pump is close to the TMP is unwanted vibration from the backing pump. Backing pumps such as dry pumps generally create considerable vibration. When backing pumps are remote from the chamber, the vibrations reaching the chamber are diminished because of the distance they must travel. When a backing pump is connected directly to a TMP, or in close proximity, the vibrations from the backing pump are transmitted to the TMP and to the chamber. This may be undesirable for certain processes. Some process equipment is sensitive to vibration because it can cause wafer movement from the set position and within metrology or lithography applications it can distort images or exposures.

SUMMARY OF THE INVENTION

[0009] An active vibration reduction system is disclosed that uses a magnetic bearing to produce a vibration to cancel an unwanted vibration. Unwanted vibration may come from a backing pump connected to a TMP, especially where the backing pump and the TMP are close together. The unwanted vibration propagates through the TMP to a host system. Vibration may be sensed where the TMP is attached to the host. For example, a sensor placed on the inlet flange of the TMP may be used. The sensor sends a signal to the TMP controller indicating the phase and amplitude of the vibration. Based on

the signal from the sensor, a modified control signal is sent to a magnetic bearing in the TMP. The modified control signal induces a vibration in the TMP that is in anti-phase with the unwanted vibration. This means that it tends to cancel the unwanted vibration resulting in less vibration in the chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1A shows a prior art pump system with a backing pump in a sub-fab.

[0011] Figure 2 shows a pumped system of the present invention.

[0012] Figure 3 shows a turbomolecular pump of a pump system of the present invention.

[0013] Figure 4 shows a pumped system according to one embodiment of the present invention.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0014] Figure 2 shows an example of a pumped system 200 that uses the present invention. TMP 210 is directly connected to a host 220 on one side and connected to a backing pump 230 on the other side. In other embodiments, lines may connect these components. The backing pump 230 is connected to an exhaust line 240 that is connected to a scrubber (not shown) that may be located in a number of different positions, for example, outside the fab 250, in the sub-Fab or within the Fab environment next to the pump 230. The TMP 210, host 220 and backing pump 230 are all located in the fab 250 in this example.

[0015] Gas is pumped from the host 220 by the TMP 210. The host 220 may be any apparatus that is pumped by a pumping system. Examples include cluster tools used in semiconductor processing such as, but not limited to, chemical vapor deposition (CVD), physical vapor deposition (PVD) or etch. The TMP 210 is typically mounted to a single chamber of a cluster tool and is dedicated to that chamber. Where several chambers are present in a cluster tool, each may have a TMP. These may each have their own dedicated backing pumps. Separate chambers may be isolated from each other so that a single chamber may be pumped at a time. Gases may be introduced into individual chambers to etch a wafer or to deposit material on a wafer. These gases must be pumped in order to maintain the necessary vacuum and to prevent process byproducts from contaminating the process. Therefore, pump size and configuration is largely dependent on the particular process used and the tool configuration.

[0016] Exhaust gas from the TMP 210 goes to the backing pump 230 and to an exhaust line that ultimately goes out of the fab. This may go to a scrubber, as shown in Figure 2, or in some other waste disposal system. This arrangement eliminates the long foreline between the TMP and the backing pump that was shown in Figure 1. The TMP 210 may be either directly connected to the backing pump 230 or may be connected by a short line with relatively small volume. Thus, the impedance between the TMP 210 and the backing pump 230 is reduced. As a result, the backing pump 230 may be smaller than it would be if a long foreline were used. Pumping down the system to its target vacuum level may also be quicker because of the reduced volume.

[0017] Figure 3 shows a TMP 310 used in the present invention, for example TMP 210 of Figure 2. The inlet 360 of TMP 310 may be connected to a host, or to a foreline by inlet flange 365. The TMP 310 includes a rotor assembly 370 that rotates at high speed to motivate gas molecules through the TMP 310. The rotor assembly 370 is driven by an electrical motor 375. Outlet 380 allows exhaust gas to be expelled from the TMP 310. Typically the outlet 380

is connected to a backing pump that provides reduced pressure at the outlet 380 of the TMP 310. Thus, the TMP 310 causes gas molecules to move from an area of high vacuum at inlet 360 to a region of moderate vacuum at outlet 380.

[0018] TMP rotor assembly 370 may be held by two different types of bearings. Magnetic bearings allow the rotor assembly to turn without physical contact with the static portions of the pump and backup mechanical bearings prevent damage to the pump by restraining the rotor assembly if the magnetic bearings fail. In Figure 3, an upper mechanical back-up bearing 385 and a lower mechanical back-up bearing 386 are positioned to capture the rotor.

[0019] Two types of magnetic bearings may be used. Passive magnetic bearings use permanent magnets to maintain the rotor position. These are simple but do not allow precise control. Active magnetic bearings use electromagnets to maintain a rotor position. By changing the current to the electromagnets the force on the rotor, and thus the position of the rotor, may be adjusted. In order to use active magnetic bearings to maintain the rotor position, the position must be accurately sensed and the current to the bearings must be adjusted in response to the sensed position. TMP 310 includes active upper x and y axes bearing 390. TMP also includes a passive lower bearing 391 that maintains the position of the lower portion of the rotor assembly 370 along the x-axis and the y-axis and an active element that maintains the rotor position in the z-axis. Because the position of the rotor is actively controlled in three axes, this is considered a three axes TMP. Five axes TMPs are also used. These are similar to TMP 310 of Figure 3 but with the passive lower bearing replaced with an active bearing. Thus, a five axes TMP has active control of the x and y axes position of the lower portion of the rotor in addition to the three controlled axes described above.

[0020] Upper radial sensor 395 monitors the position of the upper portion of the rotor assembly 370 as it spins. The radial sensor 395 is capable of detecting small deviations in the position of the rotor assembly 370 and

generating an electrical signal in response. The signal generated by the sensor 395 is generally used to modify the current in the x and y axes bearing 390 to keep the rotor assembly 370 centered within the x and y axes bearing 390. Generally, the signal from the radial sensor 395 is sent to a controller (not shown) that determines the correction that must be made to the position of rotor assembly 370 and the current necessary to achieve this. The controller then modifies the current to the x and y axes bearing 390 accordingly.

[0021] The axis of rotation of a spinning rotor is usually selected to be its inertial axis. This is not always the same as its geometric axis. This is because the rotor is not always perfectly symmetric about its geometric axis. Maintaining rotation about the inertial axis may be achieved by using a notch filter or high pass filter to give the active bearing low stiffness at the rotational frequency but high stiffness at other frequencies. In some applications the rotor may be made to spin about its geometric axis to give a maximum clearance with static portions of the TMP. This may be achieved by having high bearing stiffness at the rotational speed. Active magnetic bearings may thus maintain rotor position and reduce vibration in the TMP.

[0022] Active bearings may also be used to produce vibration. If the current to the bearing is modulated with a particular frequency, then vibration is generated between the rotor and the static portions of the pump with that frequency. Such a signal may be overlaid on the control signal that is used to maintain rotor position so that the rotor is caused to vibrate while its position is still limited by the regular control signals. For example, if an audio signal is used as an overlay, the pump may be made to "play the music."

[0023] A magnetic bearing may be used to create vibration that is in anti-phase with an unwanted vibration so that destructive interference occurs and the total vibration is reduced. Anti-phase vibration has approximately the same frequency as the original vibration but is opposite in phase. Thus the

peaks of the anti-phase vibration coincide with the troughs of the unwanted vibration and the two vibrations tend to cancel each other out.

[0024] Figure 4 shows a pumped system 400 of the present invention where a vibration is created by an active magnetic bearing 490 and the vibration is used to reduce overall vibration in the pumped system 400. A vibration sensor 467 is located on a flange 465 of the TMP 410. The vibration sensor 467 produces a signal that indicates the vibration at that point. The signal is sent to a controller 415. The controller 415 controls the active magnetic bearings 490 of the TMP 410. The signal is used by the controller to modify the current sent to the active magnetic bearings 490. Normally, a controller would modify the current only in response to a position sensor in order to keep the rotor assembly in position. Here, the signal is modified to cause the TMP 410 to vibrate so that the total vibration at the inlet flange 465 is reduced. Based on the vibration measured by the vibration sensor 467, the controller 415 calculates the magnitude and phase of vibration needed to eliminate or substantially reduce vibration at the inlet flange. The controller then modifies the current to the magnetic bearing 490 to produce this vibration.

[0025] In this example, the vibration sensor 467 is at the inlet flange 465 of the TMP 410. This location allows the vibration sensor 467 to measure vibration being passed to the host 420 from the TMP 410. In this case, the unwanted vibration comes primarily from the backing pump 430 making this a suitable location for the vibration sensor 467. However, in other embodiments, a vibration sensor could be placed in other locations and unwanted vibrations from a source other than a backing pump could be reduced. For example, a sensor could be placed on the host itself. Vibration coming from another piece of equipment attached to a host could be reduced in this way. The invention is not limited to TMPs. Other components that have magnetic bearings could be used to produce vibration that cancels unwanted vibration. This could include compressors or bobbins in textile manufacturing.

[0026] While embodiments of the present invention have been shown and described, changes and modifications to these illustrative embodiments can be made without departing from the present invention in its broader aspects. Thus, it should be evident that there are other embodiments of this invention which, while not expressly described above, are within the scope of the present invention and therefore that the scope of the invention is not limited merely to the illustrative embodiments presented.